United States Army Ordnance Munitions and Electronics Maintenance School

BASIC ELECTRICITY

PART
DIRECT CURRENT

PREFACE

Electricity is one of the most wonderful and useful of all modern discoveries. While in itself it cannot be seen, its presence is known to us through the many effects which it produces. These effects, which can be observed by our senses, include the electric spark which we can see; the crackle of this which we can hear; and the shock produced by electricity which we feel if we are not careful. Many practical applications have been found for electricity in such fields as radio, television, radar, computers, and guided missiles. It certainly must be admitted that our civilization would not be where it is today without the wonder of electricity.

Since all guided missile systems operate on the principles of electricity, it is necessary that you, as a future repairman, know and understnd these basic principles. It is the purpose of this book to present these principles in a clear and concise manner, so that even the stident who has had not prior training in electricity can comprehend the subject sufficiently. While this book can be used on a self-study basis, it is primarily designed as a reference book to be used in conjunction with the conferences in D.C. electricity taught at Redstone Arsenal.

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INTRODUCTION TO ELECTRICITY

When you turn the light switch on in a room and the lamp suddenly lights, this means that electricity has found a path through the switch to the light. What is this electricity? What makes such a simple thing as an electrical lamp light? How many people really understand why it lights? It is a simple thing to pass the problem off with the statement: "The switch connects the lamp to the power lines." What does connecting the lamp to the power line do? How does electricity travel through wires or through space? What makes a motor turn, or a radio play? What is behind the dial that allows you to pick out one radio station from thousands of others operating at the same time?

There are no simple answers to any of these questions. Each question requires the understanding of many basic principles. By adding one basic idea to another, it is possible to answer most of the questions that may be asked about electricity and electronics. So, let's start answering some of the questions by discussing three of the fundamental quantities that are present in every electric circuit: Current, voltage, and resistance.

This lesson presents some basic definitions, symbols, and fundamental concepts of electronics. The lesson begins with an explanation of common electronic terms such as voltage, resistance, current and a study of symbols used to represent some of the electronic components. If you do not understand a concept, review that section of the explanation.

A workbook, Basic Electricity Part I, has been issued by the instructor. If you need assistance or have questions, ask the instructor. If you desire additional resources and explanations concerning any topic covered in the lesson, ask the instructor. He will suggest additional training resources including reading material, tapes, and data sheets.

All physical things consist of atoms - particles so small they cannot be seen. The atom in turn consists of several kinds of still smaller particles. One such particle is the ELECTRON. The electron is a quantity or charge of electricity. The kind of electricity associated with the electron is NEGATIVE. The atom contains a nucleus, around which one or more eletrons circulate somewhat as the Earth and other planets orbit around the sun.

Study the diagram shown in FIGURE 3, and identify the protons, electrons and neutrons.

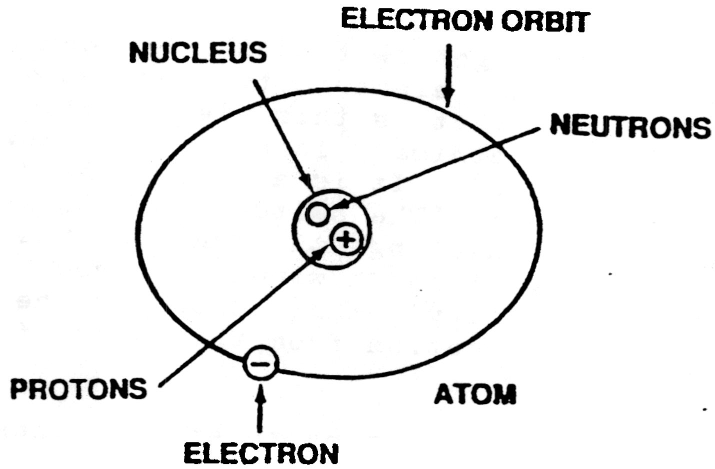


FIGURE 3 (SLIDE EP04AL-S03)

The nucleus has an electric charge of the kind of electricity called POSITIVE, the amount of its charge being equal to the sum of the negative charges of all the electrons in the orbits arouund the nucleus. The positive charges in a nucleus are called PROTONS. Protons are positive electricity. The important fact about electrons and protons is that they are strongly attracted to each other. Also, there is a strong force of repulsion between two like charges. So, opposite charges attract; and, like charges repel.

The positive nucleus, consisting of protons, and neutrons attract the negative electrons that orbit about it.

Proton - Positive charge
Neutron - Neutral
Electron - Negative charge; orbits around nucleus

The proton is a positive charge and much larger than the electron. The electron is negatively charged and is much smaller than the proton.

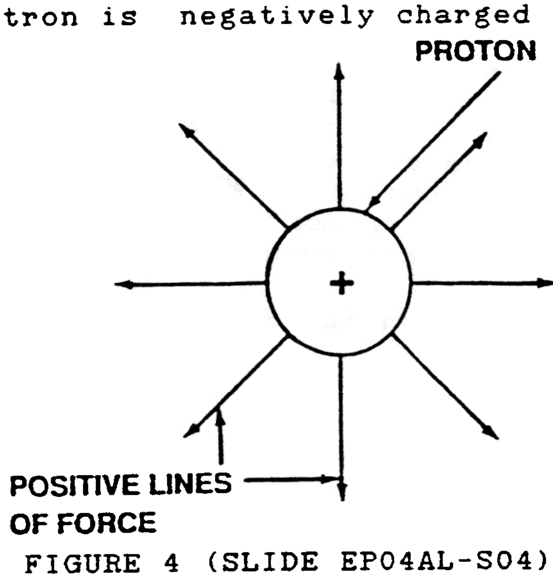


FIGURE 4 (SLIDE EP04AL-S04)

The law of attraction and repulsion states that like charges repel. As shown in FIGURE 5 two positive charges repel each other.

Proton - Positive electrical charge, produces positive lines of force.

As shown in FIGURE 5, protons repel protons.

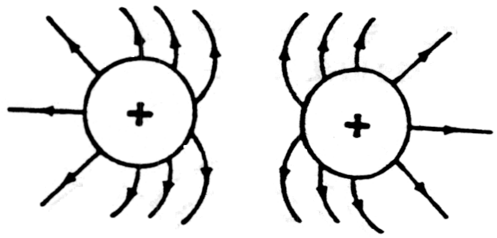


FIGURE 5 (SLIDE EP04AL-S05)

Electrons - Negative electrical charge produces negative lines of force.

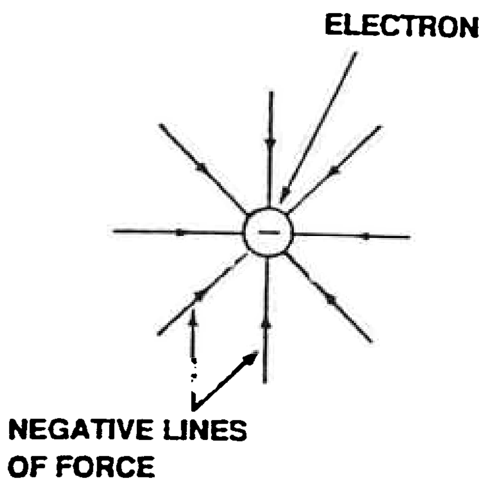


FIGURE 6 (SLIDE EP04AL-S06)

As can be seen in FIGURE 7, like negative charges repel each other, electrons repel electrons.

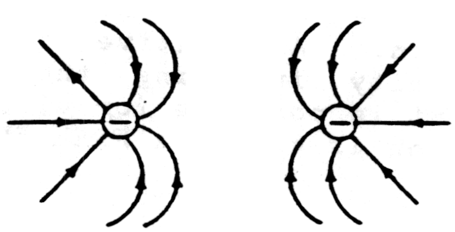


FIGURE 7 (SLIDE EP04AL-S07)

It may be concluded, then that unlike charges attract each other This may be demonstrated as shown in FIGURE 8.

CLOSE TOGETHER, ALL LINES INTERLINK

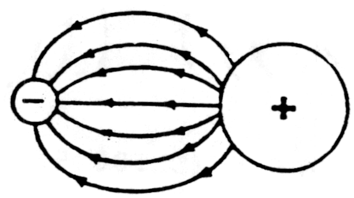


FIGURE 8 (SLIDE EP04AL-S08)

FIGURE 9 demonstrates how the attractive forces between unlike charges weaken as the distance between the charges increase.

FAR APART, THERE IS LITTLE FIELD INTERLINKAGE

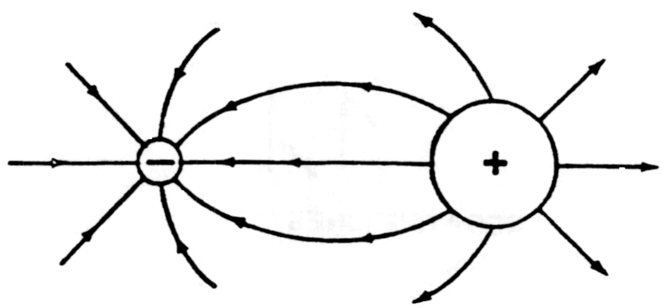


FIGURE 9 (SLIDE EP04AL-S09)

It is possible for an atom to lose one of its electrons. When this happens the atom becomes slightly positive due to the loss of a negative charge. In other words, the atom is said to be IONIZED and is referred to as a <u>positive ion</u>. If an atom picks up an extra electron, as it sometimes does, it has a net negative charge and is called a negative ion. A positive ion will attract any stray electron in the vicinity, including the extra one from a <u>negative ion</u>. In this way, it is possible for electrons to travel from atom to atom. This electron is called a FREE ELECTRON.

FIGURE 10, shows the electrons in the copper atom. Notice there is one electron in the outer shell. This electron is loosely bound to the atom and can be influenced to move to another atom.

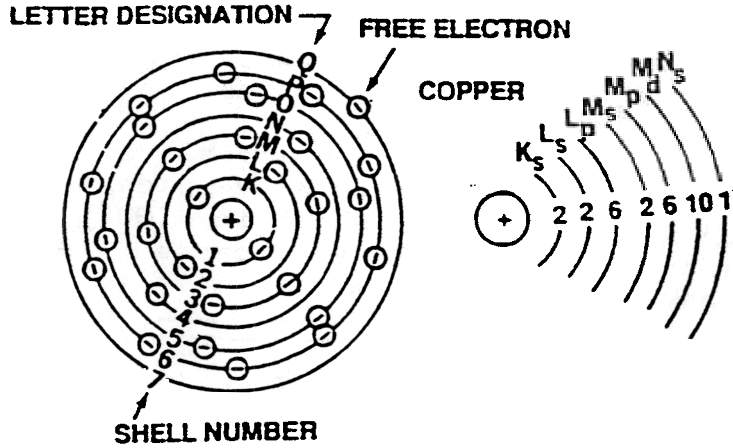


FIGURE 10 (SLIDE EP04AL-S10)

The movement of electrons from atom to atom in a material such as copper or aluminum is called electrical current or current flow. Atoms of some materials, such as metals or acids, will give up electrons, but atoms of other materials will not part with any of their electrons even when the force on the electrons is extremely strong. Materials in which electrons or ions can be moved with ease are called <u>conductors</u>, while those that refuse such movement are called nonconductors or <u>insulators</u>. Current is a movement of free electrons from atom to atom in a conductor.

Conductors	Insulators
gold	dry air
silver	glass
copper	porcelain
carbon	rubber
acids	wood

INTRODUCTION TO ELECTRICITY

Electromotive Force (EMF) is a force of elctrical pressure that can force the free electrons to move in the direction of negative to positive.

Electromotive force is developed by creating a device that produces a difference of potential between two points. This may be a device such as the battery used in an atuo.

When the battery is connected across a material with free electrons they will flow from the negative side to the positive side. If the conductor is expanded as shown in FIGURE 11, it may be seen how the difference of potential will cause electrons (-) to move (flow) from the negative to the positive (+).

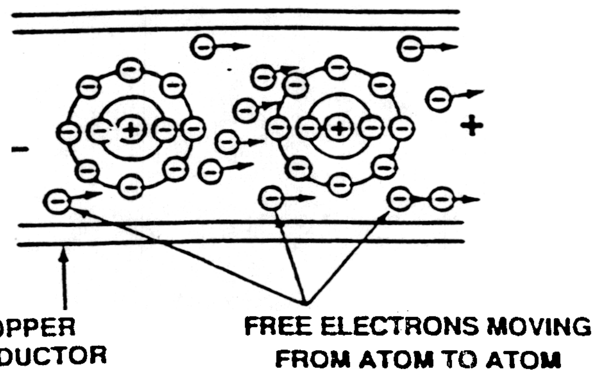


FIGURE 11 (SLIDE EP04AL-S11)

A force is required to cause electron flow or <u>current</u> from atom to atom within a conductor. This force is called an ELECTROMOTIVE FORCE, EMF, or <u>voltage</u>. It can be thought of as pressure similar in purpose to water pressure that forces water through a pipe.

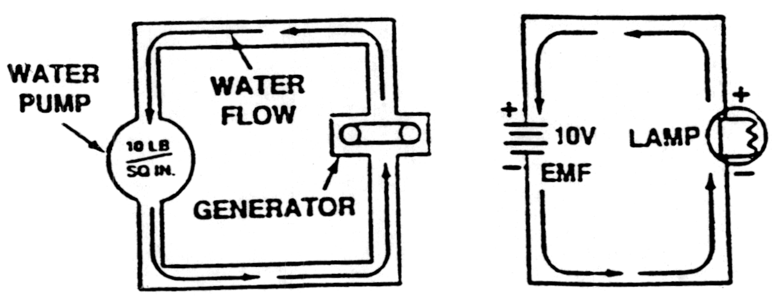


FIGURE 12 (SLIDE EP04AL-S12)

This slide shows a diagram of a water pump creating 10 pounds per square inch of water pressure. The water pressure causes water to flow from its pump through the pipe and back to the pump. The action just described is similar to an electrical current.

INTRODUCTION TO ELECTRICITY

Current flow is the movement of electrons through a conductor. The atom is composed of electrons and protons. The electron is negative in potential and the proton is positive in potential. Like charges repel and unlike charges attract. When electrons are freed from an atom and are free to join another atom, this free electron movement is called current flow.

sign denotes negative side of the battery

"+" sign denotes positive side of the battery

Current leaves the battery at the terminal marked and returns to the battery at the terminal marked "+".

Current flows from negative to positive, as shown in FIGURE 13

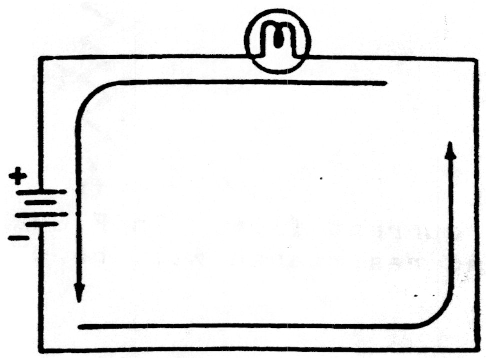


FIGURE 13 (SLIDE EP04AL-S13)

QUESTION: What is current?
ANSWER: Movement of free electrons.

QUESTION: What is the law for attraction and repulsion?
ANSWER: Like charges repel, unlike charges attract.

There are three basic relationships that exist with current, voltage, and resistance. If voltage increases, current increases. If voltage decreases, current decreases. This is called a direct relationship.

A basic circuit consists of a battery that provides the force which causes current to flow through a conductor. A direct relationship exists between voltage and current. As voltage increases, current increases. As voltage decreases, current decreases.

Thus far it has been discovered that current can and is made to flow in a conductor, having free electrons, by connecting the conductor to a battery or a source of Electromotive Force (EMF).

This understanding brings up the thought as to what will limit the current flow in the circuit?

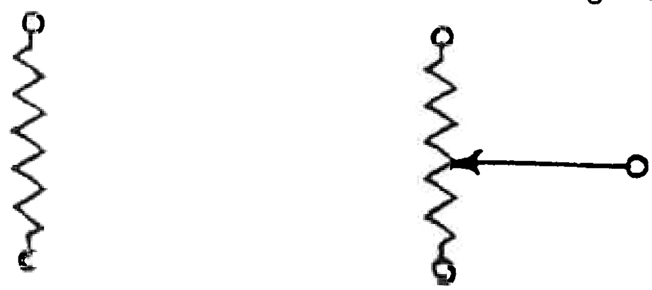
RESISTANCE can be defined as a material which, when placed in the path of current flow, will cause the current flow to be a fixed amount determined by the voltage.

Current has a unit of measure called the ampere and is designated by A, the letter symbol I is used to indicate current.

Electromotive force has a unit of measure called voltage and is designated by V, the letter symbol E, is used to indicate voltage.

The RESISTOR has as its unit of measure the Ohm and is designated by the Greek letter omega (Ω), and the letter R, is used to indicate Resistance.

There are two basic kinds of Resistors: fixed and variable. Their schematic symbols are shown in the following diagram.



Resistance opposes current flow. In FIGURE 14, the relationships of current, voltage, and resistance will be shown.

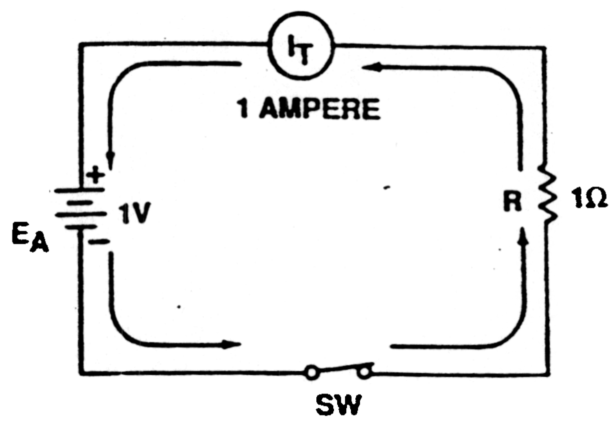


FIGURE 14 (SLIDE EP04AL-S14)

When the switch is closed, the resistor is connected to the battery through the conductors having free electrons. These free electrons are the electron movement called current flow. Thus current becomes the rate of the movement of electrons. If the electrons were counted as they passed I, in FIG. 14, 6.25×10^{18} electrons would pass I, in one second. This defined as one (1) ampere of current flow, and may be described as current equal to one volt per ohm. The symbols for this relationship can be written as:

Current Equals $\frac{\text{VOLTAGE}}{\text{RESISTANCE}}$ Symbolically $I = \frac{E}{R}$

From FIGURE 14, it can be shown that; current is directly related to voltage. This means as voltage increases current will increase. Current, however, will be inversely proportional to resistance. This means that if resistance is increased current would decrease.

In FIGURE 14, the voltage measured across the one ohm resistor would be one volt. The battery is forcing current to flow from negative to positive through the resistor.

The current in FIGURE 14, will enter the one ohm resistor at the bottom of the resistor causing the resistor to be negative (-). Thus the top end of the resistor becomes positive (+) where the current leaves the resistor. When measuring the voltage across the one ohm resistor, it is found that one volt will be dropped across the resistor. This is referred to as a voltage drop.

In FIGURE 15, it will be shown that voltage drops across the resistors add and are always equal to the battery voltage.

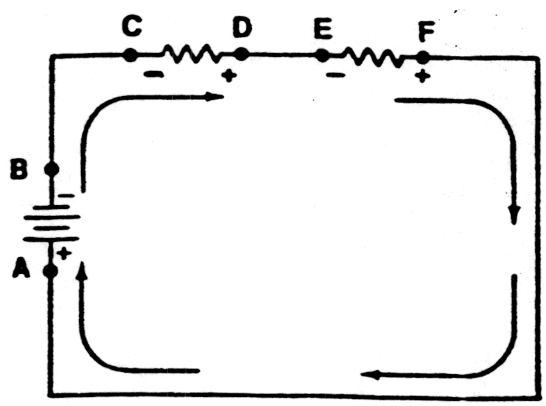


FIGURE 15 (SLIDE EP04AL-S15)

Beginning at B in FIGURE 15, current will flow toward C, entering the resistor at C. The polarity at this point is negative (-). The current will leave the resistor at D. The polarity at D will be positive (+). Part of the battery voltage will be dropped from C to D. The polarity will be negative at E and positive ar F. The remainder of the battery voltage will be dropped from E to F.

The voltage of the battery AB is equal to the voltage dropped across CD added to EF. Thus AB = CD+EF or $E_A = E_{R1} + E_{R2}$.

Some things may be noted in FIGURE 16. Point D is positive with respect to point C.

Point E is negative with respect to point F.

Point D and E are the same points electrically, and are at the same polarity. D is shown negative and E is shown positive to show the direction of current flow.

A common reference point is called ground, and the symbol for ground is ⏚. Thus all grounds are connected together electrically.

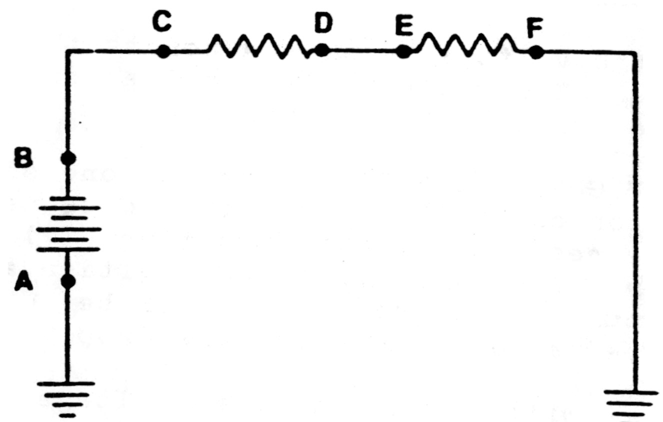


FIGURE 16 (SLIDE EP04AL-S16)

TO SUMMARIZE: The voltage developed across a resistor is called a voltage drop. The direction that current flows through a resistor determines the polarity of the voltage drop across the resistor. If batteries are placed in series, the voltages are additive. The common reference point is called ground.

Answer the following questions and read the summaries.

QUESTION: If a 2V and a 4V battery are connected in series, what is the total voltage?

ANSWER: <u>6V</u>

TO SUMMARIZE: Current that is obtained from batteries is called DC. It is constant in magnitude and direction. DC does not change direction.

QUESTION: What type of current does not change in value or direction?

ANSWER: <u>DC</u>

Ammeters are used to measure current flow and has the symbol A and is always connected in series with the circuit to be measured.

TO SUMMARIZE: A meter that is connected in series with a source to measure current is called an ammeter.

QUESTION: How is an ammeter connected in a circuit to measure current?

ANSWER: <u>Series</u>

INTRODUCTION TO ELECTRICITY

SUMMARY:

Everything is made of atoms. Atoms have a nucleus which contains protons. Protons have a positive charge.

Outside the nucleus there are electrons in orbit. Electrons have a negative charge.

Current is the movement of electrons. Voltage makes electrons move. Resistance opposes current.

E stands for voltage. R stands for resistance; I stands for current. If voltage increases while resistance remains the same, current increases. If resistance increases while voltage remains the same, current decreases.

Conductors pass current easily, insulators do not

A battery has two terminals, positive and negative. When current goes through a resistor, a voltage drop apprears across the resistance. Voltage drops have polarity.

The end of a resistor where current enters is always negative.

Current flows from negative to positive. DC (Direct Current) flows only in one direction.

Ground is a common reference point.

A circuit in which voltage is applied but current does not flow is called an open circuit.

Current is measured in amperes, voltage in volts, and resistance in ohms.